I. INTRODUCTION AND BACKGROUND

The Greater Yellowstone Network (GRYN) is one of 32 National Park Service (NPS) inventory and monitoring networks that are using ecosystem indicators—also known as "vital signs"—to assess the state of the ecosystems contained within its parks. The GRYN consists of four park units located within and around the Greater Yellowstone Ecosystem, which includes parts of Idaho, Montana and Wyoming. These units include: Bighorn Canyon National Recreation Area (BICA), John D. Rockefeller, Jr. Memorial Parkway (JODR), Grand Teton National Park (GRTE) and Yellowstone National Park (YELL). For the purposes of this report, the John D. Rockefeller, Jr. Memorial Parkway is considered part of Grand Teton National Park. A map of the parks is provided in Figure 1.1. It is the goal of this report to present an overview of the GRYN and provide information related to its strategy for monitoring vital signs.

TABLE 1.1 GRYN parks and associated acronyms.

Park Name	Alpha Code (Acronym)
Bighorn Canyon National Recreation Area	**BICA**
John D. Rockefeller, Jr. Memorial Parkway	**JODR**
Grand Teton National Park	**GRTE**
Yellowstone National Park	**YELL**

INTRODUCTION TO INVENTORY AND MONITORING

The NPS Inventory and Monitoring (I&M) Program provides an avenue for integrating inventory and monitoring activities into the parks, as well as presenting a means through which parks can collaborate and cooperate on ecosystem-wide projects. The I&M networks have the opportunity to use numerous resources to aid in planning prior to beginning on-the-ground monitoring. Thus, the products the networks produce—including protocols, standard operating procedures (SOPs) and data stewardship plans—can serve as a guide for park monitoring projects that are ongoing or funded through other sources. In addition, the I&M program integrates information from many different sources and synthesizes this information into a coherent whole that can be communicated to numerous audiences through a variety of media.

Definition of Inventory and Monitoring

To understand the state of park resources, it is necessary to first conduct an inventory of those resources. An inventory is "a point in time survey to determine the location or condition of a biotic or abiotic resource" (NPS 2004a). The initial focus

FIGURE 1.1 Map of Greater Yellowstone Network parks.

FIGURE 1.2 Map of 32 Inventory and Monitoring networks nationwide.

of the I&M networks was to conduct inventories of vertebrates and vascular plants. An inventory study plan (GRYN 2000) for the GRYN established the scope and schedule of biological inventories that were meant to provide baseline information on species occurrence in the parks.

The goal of monitoring is to detect change over time and to use this information to understand the state of the parks' ecosystems. The definition of monitoring, then, is to "detect changes or trends in the status of a resource" (NPS 2004a). Monitoring in the National Park Service is intended to aid in the development of broadly based, scientifically sound information on the current status and long-term trends in the health, composition, structure and function of park ecosystems.

The "Network" Concept and I&M Funding

The mission of the National Park Service is "to conserve unimpaired the natural and cultural resources and values of the national park system for the enjoyment of this and future generations" (NPS 2001b). To uphold this goal, the Director of NPS approved the Natural Resource Challenge in 2000 to encourage national parks to focus on the preservation of the nation's natural heritage through science, natural resource inventories and expanded resource monitoring (NPS 1999). Through the Challenge, 265 parks in the national park system were placed into seven regions and, subsequently, organized into 32 inventory and monitoring networks, based on geographic and ecological similarities (see Figure 1.2). The NPS Advisory Board suggested the following reason for creating these I&M networks:

> "A sophisticated knowledge of resources and their condition is essential. The Service must gain this knowledge through extensive collaboration with other agencies and academia, and its findings must be communicated to the public. For it is the broader public that will decide the fate of these resources" (NPS Advisory Board 2001).

Legislation

Natural resource monitoring in the national park system is mandated by a variety of laws, acts and enabling legislation. The following paragraphs provide a synopsis of those laws that are intended to guide the I&M program. A complete list of relevant legislation is contained in Appendix II.

Congress established Yellowstone National Park in 1872 as the first national park (Yellowstone National Park Act of 1872) and, in doing so, "dedicated and set apart [nearly 1,000,000 acres of land] as a…pleasuring ground for the benefit and enjoyment of the people." Grand Teton National Park, Bighorn Canyon National Recreation Area and John D. Rockefeller, Jr. Memorial Parkway were established as units in the national park system in 1929, 1966 and 1972, respectively.

The National Park Service Organic Act of 1916 established and defined the mission of NPS to be the following:

> "…to promote and regulate the use of the Federal areas known as national parks, monuments and reservations hereinafter specified…by such means and measures as conform to the fundamental purposes of the said parks, monuments and reservations, which purpose is to conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations."

Congress reaffirmed the purpose of the park units stated in the Organic Act by creating a national park system through the General Authorities Act of 1970 in which all parks were united by a common purpose of preservation. Preservation in the park units was thereby enforced even in those units whose original enabling legislation intended for them to be primarily used for recreational purposes. Within the parks of the GRYN, this is especially important in BICA, whose enabling legislation was to:

> "provide for public outdoor recreation use and enjoyment of Yellowtail Reservoir and lands adjacent thereto and for the preservation of the scenic, scientific and historic features contributing to public enjoyment of such lands and waters" (NPS 1994a).

The National Park Service then amended the Organic Act in 1978 to further strengthen the protection of resources by stating:

> "…the protection, management, and administration of these areas shall be conducted in light of the high public value and integrity of the National Park System and shall not be exercised in derogation of the values and purposes for which these various areas have been established…"

TABLE 1.2 Timeline of funds provided for GRYN activities.

Year (FY=fiscal year [Oct.-Sept.])	Funds Provided For:			
	Inventories	Planning	Water Quality	Implementation
FY2001	X	X	X	
FY2002	X	X (Phase I Report)	X	
FY2003	X	X (Phase II Report)	X	
FY2004	X	X (Draft)	X	
FY2005		X (Peer-Reviewed)	X	X
FY2006			X	X

In 1998 the National Parks Omnibus Management Act stated the intent to create an inventory and monitoring program that may be used "to establish baseline information and to provide information on the long-term trends in the condition of National Park System resources." In 2001, NPS management directed the Service to inventory and monitor natural systems in an effort to provide information for park management decisions:

> "Natural systems in the national park system, and the human influences upon them, will be monitored to detect change. The Service will use the results of monitoring and research to understand the detected change and to develop appropriate management actions" (NPS 2001a).

In addition to Service-wide mandates and enabling legislation, management plans (BICA [NPS 1994], GRTE [NPS 1995]) and business plans (YELL [NPS 2003a]) for each park require inventory and monitoring activities by requiring each park to follow NPS policies.

While additional Executive Orders and legislative acts relevant to the I&M program are described in Appendix II, one legislative act of particular relevance to the I&M program is the 1993 Government Performance and Results Act (GPRA). GPRA sets goals to help federal agencies become more accountable to the public for the money they spend and the results that are achieved. GPRA is required as part of the National Park Omnibus Management Act, which calls for the creation of Strategic Plans and Annual Performance Plans. The National Park Service created a Strategic Plan for 2001-2005 (NPS 2001b), with the Category I goal of "preserving park resources," which includes goals that fit the mission of the I&M program, such as choosing vital signs for assessing the health of park ecosystems. In addition, each park also creates five-year strategic plans and annual performance plans that guide progress toward the Service-wide goals. While a complete list of GPRA Category I goals relating to the GRYN parks can be found in Appendix II, it is important to note that the completion of Phase II of the Vital Signs Monitoring Plan (selection and approval of vital signs) fulfilled GPRA goal Ib.3.

I&M Goals and Timeline

The National I&M Program has created five major long-term goals that networks must strive to achieve (NPS 2003b). These goals include:

1. Determine status and trends in selected indicators of the condition of park ecosystems to allow managers to make better-informed decisions and to work more effectively with other agencies and individuals for the benefit of park resources.
2. Provide early warning of "abnormal" conditions and impairment of selected resources to help develop effective mitigation measures and reduce costs of management.
3. Provide data to better understand the dynamic nature and condition of park ecosystems and to provide reference points for comparisons with other altered environments.
4. Provide data to meet certain legal and Congressional mandates related to natural resource protection and visitor enjoyment.
5. Provide a means of measuring progress toward performance goals.

To fulfill these goals, the networks are divided into groups and placed on staggered schedules to complete inventories, planning, monitoring plans and implementation of monitoring protocols. The timeline for the GRYN is presented in Table 1.2.

TABLE 1.3 Park area and 2002 visitation.

	BICA	GRTE	YELL
2002 visitation (millions)	*0.18*	*2.6*	*3.0*
Land area managed by park (in millions of acres)	*0.12*	*0.31*	*2.2*

INTRODUCTION TO GRYN PARKS AND RESOURCES

Grand Teton and Yellowstone National Parks create the core of the 18 million acre Greater Yellowstone Ecosystem (GYE [GIAC 2003]), one of the largest, relatively intact ecosystems in the contiguous United States. With the addition of Bighorn Canyon National Recreation Area, the network also encompasses the cold desert landscape of the eastern foothills in the northern Rocky Mountains. This section describes significant natural resources within the parks, as well as ecosystem-wide resources and issues, such as air and water quality. Please see Table 1.3 for a synopsis of park area and recent visitation numbers.

Bighorn Canyon National Recreation Area

Bighorn Canyon National Recreation Area (Figure 1.3), located in southeastern Montana and north-central Wyoming, was created in 1966, following the construction of the Yellowtail Dam on the Bighorn River, in large part to provide for recreational use of the dam. Park boundaries also encompass a potrion of the Pryor Mountain Wild Horse Range (managed chiefly by the Bureau of Land Management) and Yellowtail Wildlife Habitat Area (managed cooperatively with the Wyoming Game and Fish Department), which provides habitat for waterfowl, upland game and raptors.

The topography of BICA is characteristic of the Intermountain Semidesert Province (Bailey 1995), which consists of plains surrounded by the foothills of the Bighorn and Pryor Mountains. BICA lies in the rain shadow of the Beartooth Mountains (Nesser et al. 1997), leading to a semiarid environment with an average annual precipitation of 15 inches (38 cm; Western Regional Climate Center 2004). A large gradient of precipitation separates the dry southern end of the park from the less arid northern end. Temperatures can range from over 100°F (38°C) to less than –20°F (-29°C [Western Regional Climate Center 2004]).

Yellowtail Dam is operated by the Bureau of Reclamation and dominates the hydrology of the Bighorn Canyon area. The Bighorn

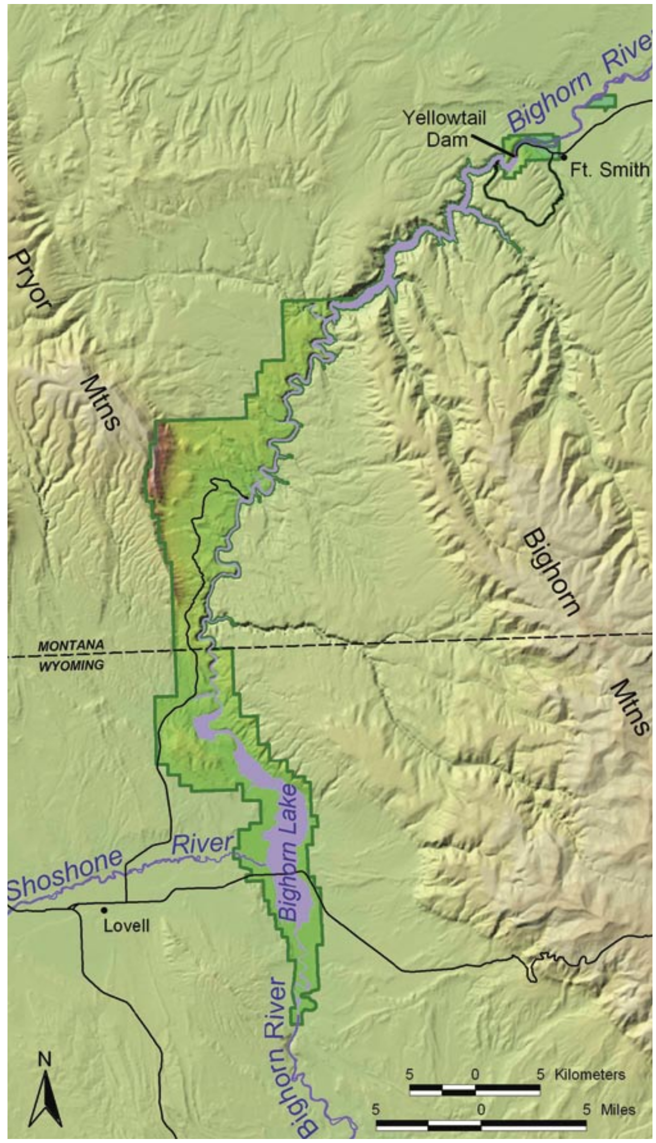


FIGURE 1.3 Bighorn Canyon National Recreation Area.

and Shoshone Rivers, along with other smaller streams that originate in the Bighorn and Pryor Mountains, supply Bighorn Lake and drain into the Yellowstone River. The Shoshone River originates in the Absaroka Mountains (located on the eastern edge of Yellowstone) and meets the Bighorn River in the Yellowtail Wildlife Habitat Area. Both cold and warm water fish species live in Bighorn Lake, which is managed for recreational sport fishing by the Montana Department of Fish, Wildlife and Parks and the Wyoming Game and Fish Department.

The vegetation in BICA is dominated by juniper/mountain mahogany woodlands. Other major vegetative communities include limber pine, desert shrublands, sagebrush steppe, grasslands, riparian habitats and ponderosa pine savannah (Knight et al. 1987). Soils are generally alkaline aridisols, entisols or vertisols and mostly contain lime- or gypsum-enriched subsoils that develop into a caliche hardpan (NPS 2003d).

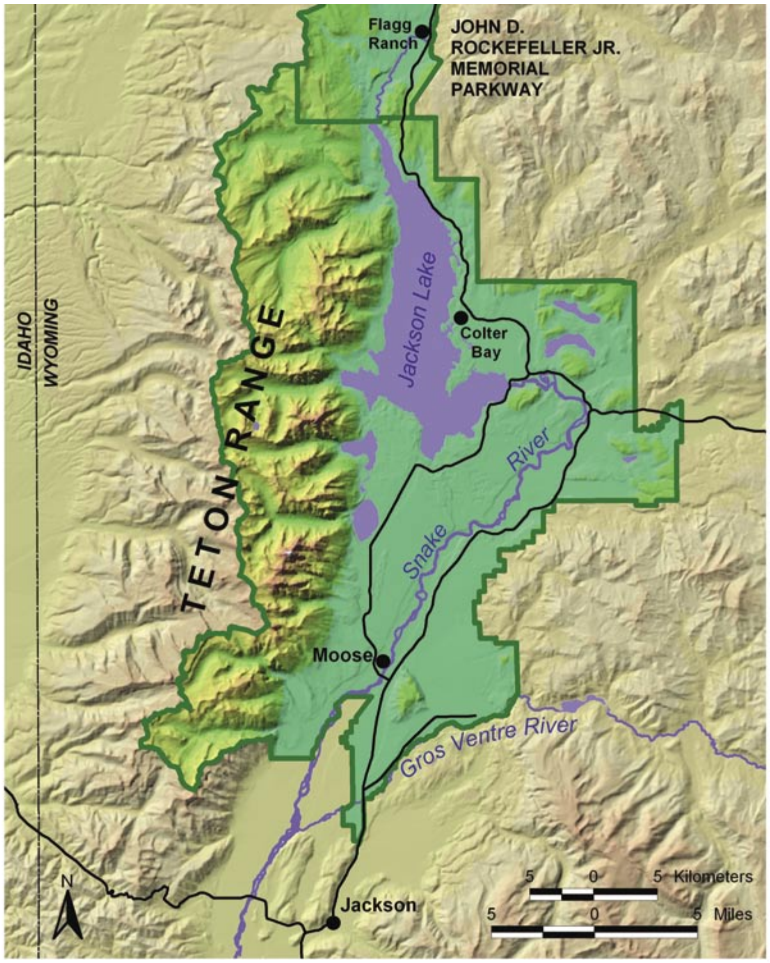


FIGURE 1.4 Map of Grand Teton National Park

Grand Teton National Park

Grand Teton National Park (Figure 1.4), located in western Wyoming, was created in 1929. The purpose of the park, as stated in the Master Plan (NPS 1995), is to "protect the scenic and geological values of the Teton Range and Jackson Hole, and to perpetuate the Park's indigenous plant and animal life." Grand Teton National Park also administers the 23,777-acre John D. Rockefeller, Jr. Memorial Parkway, established in 1972 to honor the contributions of its namesake to the conservation movement.

GRTE is famous for its topography, including 12 peaks above 12,000 feet in elevation, which developed along the north-south Teton Fault. Subsequent glacial activity further sculpted the Teton Range, and perennial glaciers and ice fields occupy some protected recesses within the range. Average snowfall in the park is 191 inches (485 cm), but varies with elevation and location. The park is said to be semiarid, with temperature highs approaching 100°F (38°C) and an extreme recorded low of –46°F (–43°C [NPS 2004b]).

Approximately ten percent of Grand Teton National Park is covered by surface water. The park contains more than 100 alpine lakes, ranging in size from one to 60 acres, many above 9,000 feet in elevation. All surface and groundwater in the park drains into the Snake River. Jackson Lake Reservoir is operated by the Bureau of Reclamation, which retains exclusive control of the flow and utilization of water in the reservoir, except water reserved for Snake River fisheries. The National Park Service and Wyoming Game and Fish Department cooperatively manage fisheries within the park. Several lakes are stocked with fish (including one nonnative species in Jackson Lake) as part of a sport fisheries program.

The Snake River floodplain, which dominates the valley floor of the park, consists of riparian forest (e.g., cottonwood, willow and aspen). Terraces rising above the floodplain, primarily covered by sagebrush and grasses, are occasionally interrupted by glacial moraines and buttes. The forests consist mainly of lodgepole pine, Douglas-fir and aspen at lower elevations, while Engelmann spruce, whitebark pine and subalpine fir inhabit higher elevations.

Yellowstone National Park

In 1872 Yellowstone National Park (Figure 1.5) was created as the world's first national park, due to its vast array of wildlife and geothermal features. The United Nations designated Yellowstone as a Biosphere Reserve on October 26, 1976, stating:

> "Yellowstone National Park is recognized as part of the international network of biosphere reserves. This network of protected samples of the world's major ecosystem types is devoted to conservation of nature and scientific research in the service of man. It provides a standard against which the effect of man's impact on the environment can be measured."

Furthermore, on September 8, 1978, the United Nations, at the request of President Richard Nixon, designated Yellowstone a World Heritage Site, stating:

> "Through the collective recognition of the community of nations . . . Yellowstone National Park has been designated as a World Heritage Site and joins a select list of protected areas around the world whose outstanding natural and cultural resources form the common inheritance of all mankind."

One of the primary reasons for these designations is the plethora of geothermal features found within the park. Almost 500 geysers—

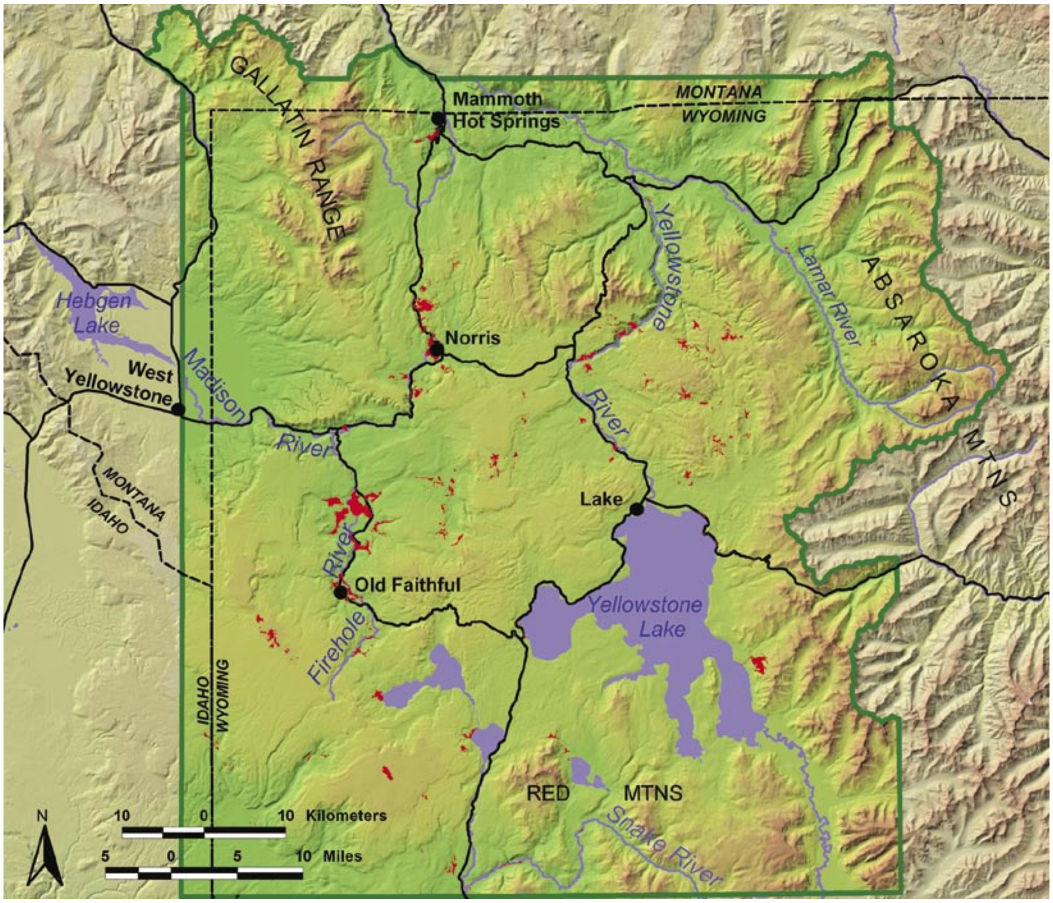


FIGURE 1.5 Map of Yellowstone National Park with thermal areas shown in red.

nearly two-thirds of those on Earth—and more than 10,000 hot springs, fumaroles and mud pots are found within park boundaries (Monteith 2003). Cataclysmic eruptions 2 million, 1.3 million and 630,000 years ago produced the Yellowstone caldera, and magma, located in some places only one to three miles below the Earth's surface, continues to supply heat to the groundwater that creates the features. These features also contain microorganisms, called thermophiles, and one endemic plant species—Ross's bentgrass (*Agrostis rossiae* [YELL 2004a]).

Most of the park is above 7,500 feet in elevation and is dominated by a flat, high-elevation volcanic plateau. The park encompasses part of the Gallatin Mountains to the northwest, the Absaroka Mountains to the east and northeast and the Red Mountains to the south. Due to the variation in topography, it is often stated that Yellowstone has two climates (Despain 1987). Average temperatures at Mammoth Hot Springs range from 9°F (-13°C) in January to 80°F (27°C) in July. The record high temperature in the park was 98°F (37°C; Lamar in 1936), with a record low of -66°F (-54°C; Madison in 1933). Average precipitation also varies, from 10 inches (26 cm) at the north boundary to 80 inches (205 cm) in the southwest corner (YELL 2004b). Snow accumulation provides the primary source of precipitation for the park.

The watersheds in YELL drain into the Yellowstone and Madison Rivers east of the Continental Divide, and into the Snake River to the west. Yellowstone Lake is the most prominent lake in the park with a surface area of 136 miles^2 (352 km^2). More than 634 lakes and ponds comprise approximately 107,000 surface acres (43,301 hectares) in Yellowstone—94 percent constitute Yellowstone, Lewis, Shoshone and Heart Lakes—while 1,000 rivers and streams create approximately 2,463 miles of running water (YELL 2004a).

Yellowstone Lake and Yellowstone River together contain the largest population of native cutthroat trout in the world (YELL 2004a). Four native fish—the fluvial form of Arctic grayling, westslope cutthroat trout, Yellowstone cutthroat trout and Snake River cutthroat trout—that inhabit the waters of Yellowstone are thought to be at risk. Cutthroat trout are of particular concern due to decreases in their population size and their importance as a food source for threatened grizzly bears (YELL 2004a). Lake trout—a nonnative fish that inhabits the waters of Yellowstone—are thought to out-compete cutthroat trout and may be a leading cause of decline in the cutthroat trout population (YELL 2004a).

Four of the five vegetation zones in Yellowstone are underlain by bedrock of volcanic origin and contain forests—interspersed with subalpine meadows and alpine tundra—that are dominated by lodgepole pine, Engelmann spruce, subalpine fir or whitebark pine. The Northern Range, a low-elevation vegetation zone underlain by glacial debris of volcanic and sedimentary composition, is located along the Yellowstone and Lamar River valleys and provides critical winter range for elk, bison and other ungulates. This area is dominated by sagebrush steppe and grasslands.

NATURAL RESOURCE THREATS AND ISSUES

Although the parks of the Greater Yellowstone Network serve as refuges for numerous flora and fauna, natural resources in the parks face a variety of threats from outside and within park boundaries. Following is a synopsis of these threats (which is not meant to be a thorough review of all possible threats) organized under broad topic categories created by the National I&M Program as a "vital signs framework." Thorough, detailed information on threats and issues related to selected GRYN vital signs can be found in the individual monitoring protocols.

The integrity of biological systems is threatened in numerous ways within the parks of the GRYN. Most notably, changes in species composition, including numbers and types of species inhabiting ecosystems in the parks, are a threat to native species viability and trophic cascades. The introduction of nonnative species—both terrestrial and aquatic—can often lead to widespread invasion of habitat for native species. In addition, the introduction of exotic diseases and insect outbreaks can lead to the destruction of native species or their habitat.

Water quality in the parks is threatened by nitrogen deposition, changes in hydrologic regime and exotic species introduction. High-elevation watersheds in the GRYN are thought to be highly impacted by atmospheric deposition (particularly nitrogen), primarily due to their underlying thin soils and resistant bedrock that limit acid-neutralizing capacity (Kashian 2004). Other forms of pollution, including trace elements, mercury and pesticides, may also threaten aquatic resources in the GRYN. In addition, changes in hydrologic regimes can result from climate change, diversions and damming; this can lead to flow alteration, changes in water temperature and shifts in community composition (Kashian 2004). Furthermore, whirling disease, New Zealand mud snails and lake trout have been introduced to the system and have led to the decline of native communities.

With respect to geology and soils, potential geothermal development outside the boundaries of Yellowstone National Park could lead to reductions in the flow of water in the basins, causing disruptions to geothermal features in the park. In addition, loss of biological soil crusts is occurring in Bighorn Canyon due to wild horse, cattle and native ungulate trampling. These crusts contain important organisms that help protect desert soils from erosion.

Ecosystem patterns and processes can be disrupted by changes in land use, another issue around the GRYN parks. Increases in the size of surrounding cities and towns can lead to habitat fragmentation, which may adversely affect species that migrate outside of park boundaries, as their migration routes can be lost and important habitat may be unavailable. These impacts are especially devastating to those species that have large home ranges. Increases in human use inside the parks (i.e., visitation, day use, backcountry day and overnight use) may also impact flora and fauna.

Changes in climate can have wide-ranging impacts on ecosystems, from alterations in species distributions to species extinctions and altered fire regimes. Ozone, nitrogen, sulfur and organochlorine compounds—in the form of atmospheric deposition—can become concentrated in snow pack at high elevations and affect water chemistry.

OUTSTANDING NATURAL RESOURCES: STATUS AND CURRENT MONITORING

The following section is a summary of the status and current monitoring of threatened and endangered species and air and water resources. Further information on current monitoring taking place in the GRYN, along with Web links, can be found in Appendix II.

Threatened and Endangered Species

Four threatened or endangered species inhabit the parks of the Greater Yellowstone Network: gray wolves, bald eagles, Canada lynx and grizzly bears. Following is a summary of current monitoring and status for each species. Further information on current monitoring for these species, along with Web site links, can be found in Appendix II.

4A. GRAY WOLVES

Although listed as a nonessential, experimental species under the final U.S. Fish and Wildlife Service (USFWS 1994) ruling, national parks are directed to manage wolves as a threatened species under Section 10(j) of the Endangered Species Act. In Yellowstone, wolves have been monitored since their reintroduction in 1995 and 1996; this monitoring includes information on population dispersal, distribution, reproduction, mortality and predation of ungulates (Smith et al. 2003).

After their 70-year absence from Jackson Hole, gray wolves returned to Grand Teton National Park in the fall of 1998, when two groups from the Yellowstone reintroduction appeared. Most of the monitoring ongoing outside of Yellowstone National Park is lead by USFWS and USFS staff and consists of censusing, monitoring of reproduction and mortalities, and movement and dispersal patterns (USFWS et al. 2004). Science and Resource Management personnel at Grand Teton locate radio-collared wolves using aerial surveys and conduct ground-based observations of packs in the region from May through September (GRTE 2004). Please see Appendix II for links to reports and further information on monitoring outside the parks.

4b. Bald Eagles

Significant increases in population numbers caused the USFWS to downlist the bald eagle from endangered to threatened in 1995 (McEneaney 2004). When the eagle was originally chosen as the national symbol in 1782, some 100,000 nesting pairs of bald eagles resided in the continental United States. By 1963, their numbers were down to 417 pairs (USFWS 1999). A loss of nesting habitat, coupled with the use of DDT and other organochlorines, which caused thinning of egg shells and decreased nesting success, lead to the decline in bald eagle populations (USFWS 1999). Captive breeding programs, reintroduction efforts, nest site protection and law enforcement helped in the recovery effort (USFWS 1999).

Yellowstone National Park publishes an annual report documenting the population status, territorial occupancy and nest productivity of the bald eagle. Bald eagle monitoring has been ongoing in Grand Teton National Park since the 1970s, including ground surveys for nests and monitoring reproductive status at historical nests (Wolff 2003). Bald eagle nests south of Bighorn Canyon National Recreation Area are currently monitored by Wyoming Game and Fish and the Bureau of Land Management (D. Saville pers. comm.). This monitoring is mostly within the boundaries of the Yellowtail Wildlife Habitat Area, but also extends approximately 0.5 miles into BICA boundaries (B. Pickett pers. comm.). Please see Appendix II for links to reports and information on monitoring by the Greater Yellowstone Coordinating Committee outside the parks.

4c. Canada Lynx

In March 2000, the USFWS listed the Canada lynx as a threatened species (USFWS 2000). Canada lynx were listed as threatened due to the inadequacy of forest plans to provide for protection of the ecological needs of lynx. National forest and park resource management plans have been amended, and a strategy is now in place for the conservation of lynx and their habitat. Threats include loss of connectivity between isolated ecosystems supporting lynx, incidental mortality during otherwise lawful trapping, hunting and snaring of other animals, and human encroachment on wildlands (USFWS 2003).

An inventory of Canada lynx in Yellowstone National Park was completed in 2004. Using a variety of survey methods, Canada lynx adults and kittens were detected in the park, with most detections occurring in an area near Yellowstone Lake that supports forests with dense understory vegetation (Murphy et al. 2004). It was concluded that the Canada lynx suffers from reduced population viability in the park, probably because the park represents the limit of its range (Murphy et al. 2004).

GRTE has completed a three-year study in collaboration with the Wildlife Conservation Society to determine (a) the status of lynx in the park, and (b) the activity of their primary prey, snowshoe hares. Results from these efforts will provide information for the determination of coarse-scale habitat requirements and, ultimately, what role Grand Teton plays in the overall conservation of lynx.

4d. Grizzly Bears

Grizzly bears were listed as threatened under the Endangered Species Act on July 28, 1975 (USFWS 1993). At the time of listing, they occupied only two percent of their original range in the continental United States and numbered 800 to 1,000 individuals in five or six populations (USFWS 1993). After listing, work began on the recovery plan for the species, which was approved on January 29, 1982, with revisions made in 1993 (USFWS 1993). The primary threats to grizzly bear populations are loss of habitat due to fragmentation, and adverse bear-human interactions, which leads to the destruction of "nuisance" bears (USFWS 1993). Human encroachment into grizzly habitat is a major threat because of the bears' very large home ranges that cover 309-537 square miles for females and 813-2,075 square miles for males (YELL 2004a).

In an effort to provide information to assist with long-term management of grizzly bears in the GYE, the Interagency Grizzly Bear Study Team (IGBST) was formed in 1973. This team has representatives from the following agencies: U.S. Geological Survey, National Park Service, U.S. Forest Service, U.S. Fish and Wildlife Service, Idaho Department of Fish and Game, Montana Fish, Wildlife and Parks, and the Wyoming Game and Fish Department. The IGBST is responsible for: "conduct[ing] both short- and long-term research projects addressing information needs for bear management; monitor[ing] the bear population, including status and trend, numbers, reproduction and mortality; monitor[ing] grizzly bear habitats, foods and impacts of humans; and provid[ing] technical support to agencies and other groups responsible for the immediate and long-term management of grizzly bears in the GYE" (Schwartz and Moody 2004). For further information on recovery goals, the IGBST and bear management activities in YELL, please consult Appendix III.

Air Resources within the Greater Yellowstone Network

Grand Teton and Yellowstone National Parks have been designated Class I areas under the Clean Air Act (YELL 2004a). The purpose of the Clean Air Act is to "preserve, protect, and enhance the air quality in national parks, national wilderness areas, national monuments, national seashores, and other areas of special national or regional natural, recreational, scenic, or historic value" (YELL 2004a). Section 169(A) of the Clean Air Act clearly identifies the goals of air quality monitoring in Class I areas:

> "Congress hereby declares as a national goal the prevention of any future, and the remedying of any existing impairment of visibility in mandatory Class I Federal areas which impairment results from any manmade air pollution."

In accordance with its classification as a Class I area, visibility monitoring is ongoing in Yellowstone National Park as part of the Interagency Monitoring of Protected Visual Environments (IMPROVE) program. IMPROVE is composed of members from federal, state and regional agencies and has the common goal of providing information to protect visual environments under the Clean Air Act of 1977 (IMPROVE 2004). The program was initiated in 1985 to protect visibility in Class I airsheds in 156 national parks and wilderness areas.

Passive ozone monitoring was conducted from 1995 through 2004 to determine ozone exposure levels at GRTE. Data collected from this site can be downloaded from: http://www2.nature.nps.gov/air/studies/passives.htm. Passive ozone monitoring is an inexpensive method that involves exposing the passive sampler to ozone on a weekly basis during the "ozone season" from May to September. After exposure, the sampler is retrieved and mailed to a contract lab for analysis. The passive ozone monitoring program was supervised and funded by the NPS-ARD and was discontinued in 2005. Please see Figure 1.6 for a map of current air quality monitoring stations withinn the GRYN.

In addition to visibility monitoring, atmospheric deposition monitoring is ongoing in YELL through two major programs: the National Atmospheric Deposition Program/National Trends Network (NADP/NTN) and the Clean Air Status and Trends Network (CASTNET). NADP is a multi-agency (including federal, state and local) approach to monitoring the chemistry of wet deposition throughout the country at over 200 sites (NADP 2004). NADP/NTN currently operates one station at Tower Falls in Yellowstone National Park that collects information on daily, weekly, seasonal and annual totals and trends for the site (NADP 2004). NADP also operates a Mercury Deposition Network (NADP/MDN) that collects information on weekly total mercury concentrations in precipitation, as well as seasonal and annual mercury flux. An MDN station was started at Yellowstone Lake in February 2002 and moved to Tower Falls in 2005.

CASTNET is a joint venture between the Environmental Protection Agency (EPA) and the National Park Service-Air Resources Division that operates more than 70 dry acidic deposition sites throughout the U.S. (EPA 2004). These sites provide hourly data on ozone levels and weekly information on the concentration of sulfate,

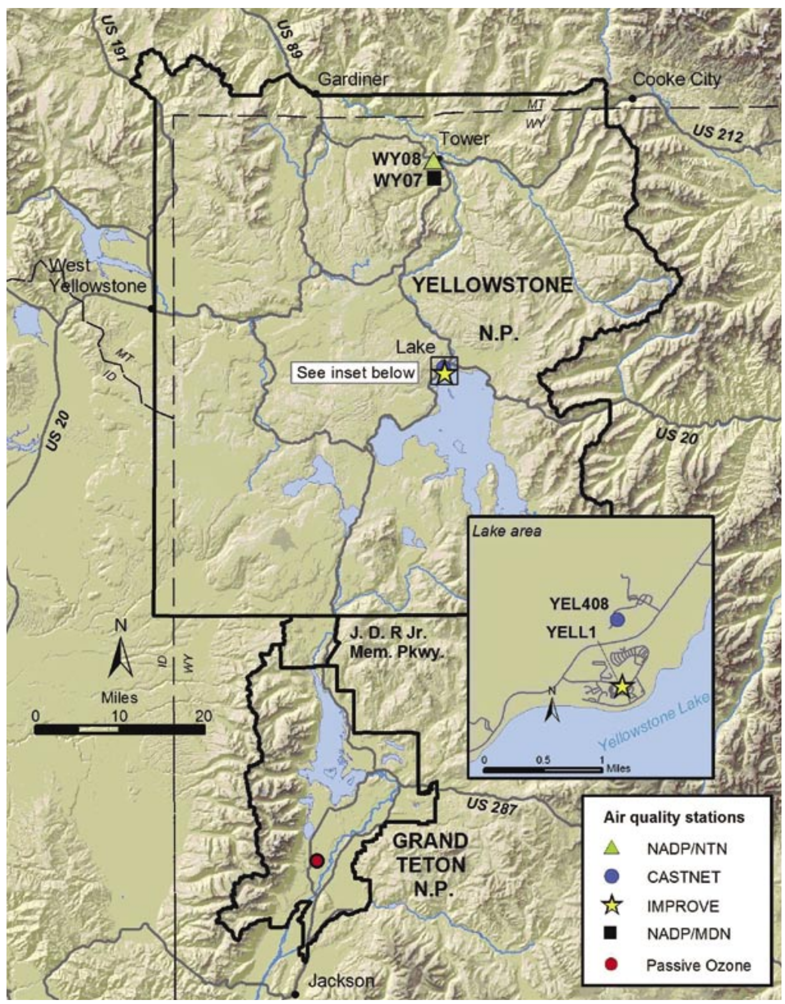


FIGURE 1.6 Map of air quality monitoring stations with new MDN location and added passive ozone site in GRTE (coordinates from GRTE GIS). Source: NPS-Air Resources Division

nitrate, ammonium, sulfur dioxide and nitric acid (EPA 2004). One CASTNET site is currently located near Yellowstone Lake. Please refer to Appendix II for more information on air quality monitoring.

Water Resources within the Greater Yellowstone Network

The state of Wyoming has classified all surface waters located within the boundaries of Yellowstone and Grand Teton National Parks as Class 1 waters. Class 1 waters are defined by the state as "those surface waters in which no further water quality degradation by point source discharges other than from dams will be allowed" (Wyoming DEQ 2001). The classification of these waters corresponds with the EPA Outstanding Natural Resource Waters (ONRWs) designation, giving them the highest level of protection from degradation (EPA 1994).

Section 303(d) of the Clean Water Act requires states to assess their waters to determine which water bodies are impaired or threatened and to develop water quality improvement strategies for these waters. Every other year, a list of these waters is submitted to the EPA. Bighorn and Shoshone Rivers in BICA, Reese Creek in northern Yellowstone and Soda Butte Creek (outside the Yellowstone boundary) are 303(d)-listed streams that will be monitored as part of the regulatory water quality monitoring by the GRYN (Wyoming DEQ 2002; Montana DEQ 2002). See Table 1.4 for locations of 303(d)-listed streams within network parks.

Surface water quality data retrievals from six of the USEPA's national databases served as the basis for the Baseline Water Quality Data Inventory and Analysis Reports completed for YELL, GRTE and BICA by the Servicewide Inventory and Monitoring Program and the Water Resources Division (National Park Service 1994b, 1998, 2001c). These data were later acquired and analyzed for state water quality exceedances by Woods and Corbin (2003a, 2003b, 2003c). Knauf and Williams acquired and analyzed seven data sets for Soda Butte Creek (2005), dating from 1987 to 2001; these data were submitted to EPA for submission to the EPA STORET database. In 2004 the GRYN prepared a phase II Water Quality Monitoring Plan (O'Ney and McCloskey 2004) to address overall water quality goals, background information and conceptual models for water quality monitoring in the GRYN. These reports can be found on the Web at: http://www.nature.nps.gov/im/units/gryn/index.shtml.

In 2005 the GRYN, together with the network parks, began monitoring water bodies identified as water quality impaired following the Regulatory Water Quality Protocol (O'Ney 2005); these streams include Soda Butte Creek, Reese Creek and the Bighorn River in Montana and Shoshone River in Wyoming. The Regulatory Water Quality Monitoring Protocol for the Greater Yellowstone Network (O'Ney 2005) establishes the standing operating procedures for measuring core parameters and discharge plus dissolved and total metals in water, metals in sediment, nutrients, *E. coli* and fecal coliforms and macroinvertebrates. Please see Table 1.4 for a summarization of trends in water bodies to be monitored by the GRYN.

Both Yellowstone and Grand Teton NP's have on-going monitoring water quality within their boundaries. The following section describes water quality monitoring currently being done by the YELL aquatic resource division in YELL and by park staff at GRTE. See also sections on geothermal and streamflow monitoring for more information on water related monitoring.

At the USGS gauging station at Moose (GRTE), there is a real-time, continuous monitor for water temperature, pH, dissolved oxygen and specific conductivity. Also in GRTE, approximately 20 groundwater wells adjacent to sewage ponds and leach fields within park boundaries are presently being monitored once a year for basic water quality parameters, fecals and nutrients to comply with the requirements of Wyoming Department of Environmental Quality. Additionally, Snake River Pit ground water levels are monitored on a biweekly basis from wells installed by the USGS in 1997 (O'Ney and McCloskey 2004). Testing for fecal coliform, including DNA source tracking of *E. coli* to determine the mammalian source of coliforms, began in 1996 in selected backcountry streams, and has continued to date (O'Ney and McCloskey 2004).

A long-term water quality monitoring program was started in YELL in 2002 and includes nineteen fixed sites; twelve of these stations are located on rivers and streams and seven are located on Yellowstone Lake. Field measurements include pH, dissolved oxygen, specific conductance, temperature and turbidity; samples are collected for total suspended solids (TSS) and volatile suspended solids. Sampling takes place at two-week intervals during the spring, summer and fall and monthly during the winter (December, January and February). On Yellowstone Lake, monitoring stations were established at four historic sampling stations (Koel et al. 2004), with sampling taking place between May and October (during ice-free periods). Two additional sampling sites on the southern arms of Yellowstone Lake were added in 2003 for a total of seven stations on the lake.

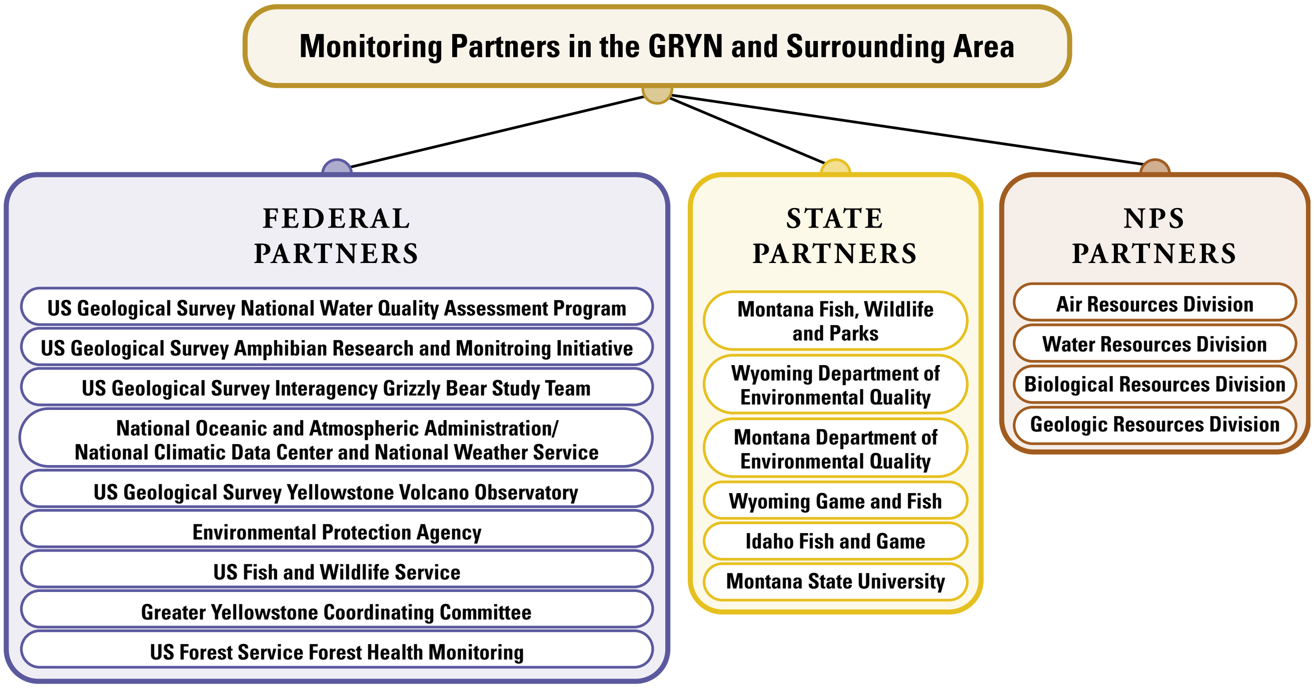


FIGURE 1.7 The National Park Service is involved with many other federal agencies and state agencies to complete monitoring within and around the parks of the GRYN. This figure is meant to illustrate the importance of these monitoring efforts and is not meant to be an exhaustive list of all organizations and agencies monitoring resources within the ecosystem. Appendix II of this report describes current monitoring programs taking place in the GRYN in more detail.

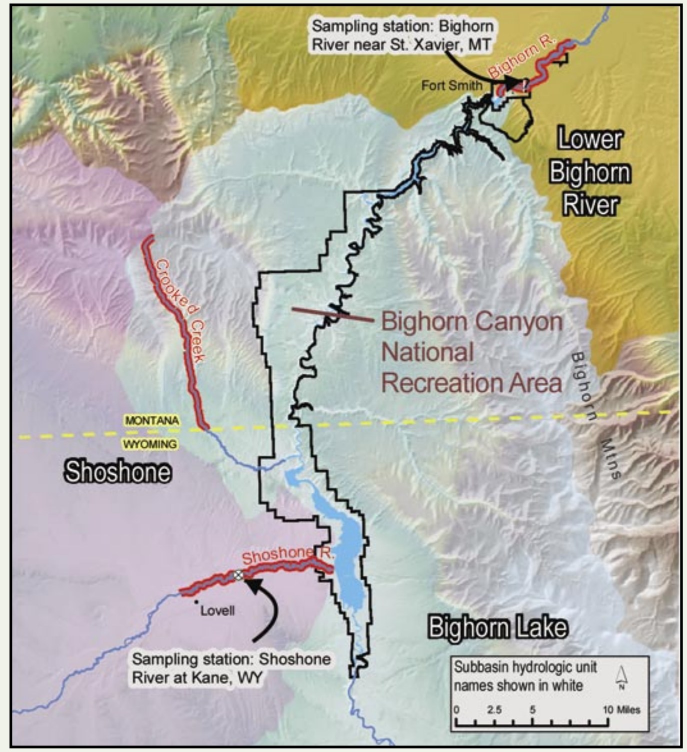
Streamflow (real time discharge and gage height) is being monitored by the USGS at several locations in the GRYN. This monitoring is often in cooperation with other state and federal agencies including YELL geothermal program and other cost share with GRTE. See Appendix II for a table of key streamflow gages in the GRYN. Data can be obtained from http://waterdata.usgs.gov/nwis. These gages are usually located on the mainstem of larger rivers at easily accessible sites. While this network provides invaluable information on regional hydroclimatic variability, the lack of gages in headwaters areas or on smaller tributaries may represent and important data-gap for the GRYN. Smaller streams generally respond more rapidly to variations in climate (NAST 2001; Wagner 2003). Small streams also provide key habitats for species of interest within the Greater Yellowstone Ecosystem (e.g. cutthroat trout).

Other Natural Resource Monitoring

Numerous types of natural resource monitoring are ongoing in the GRYN parks and surrounding landscapes. Understanding the scope of these projects, along with the goals and objectives of the agencies or groups conducting the monitoring, allows the GRYN to integrate with these programs to achieve a more balanced and efficient program. Appendix II contains a detailed explanation of current monitoring in the GRYN parks and surrounding lands. Figure 1.7 presents a brief overview of those federal, state and park partners that are currently involved in monitoring some aspect of one or more GRYN vital signs. This figure is not an exhaustive list, nor does it include those organizations that actively participate in research in the GRYN parks and surrounding landscapes. For the purposes of the I&M program it is most important to understand which groups are currently involved in taking repeat, standardized measurements that can provide information to help assess the state of the ecosystems contained within these parks. Integration with these agencies and groups is essential to the success of the GRYN; the GRYN can take advantage of the ongoing momentum of established programs and increase efficiency and cost-effectiveness by combining efforts. This can lessen redundancy, lead to shared resources and more effectively cross political boundaries. For information regarding integration with other ongoing monitoring programs (with respect to design issues), please consult Chapter 5; for additional information on program integration, please see Chapter 8. Developing Vital Signs and Monitoring Objectives—An Overview of the Program

TABLE 1.4 Exceedances of state water quality standards, potential causes and water quality trends for waters in GRYN sub-basins taken from Woods and Corbin (2003 a,b&c). Many sampling locations were of limited value in determining trends due to either a lack of data for a particular parameter or a lack of sufficient data points. Refer to Woods and Corbin for a more detailed discussion, including information on potential data outliers. See also Montana and Wyoming DEQ water quality assessment reports (WYDEQ 2004, MTDEQ 2004) for additional sub-basin information. Streams segments (within or near the park boundary) that are listed as 303 (d) water quality impaired are show in red.

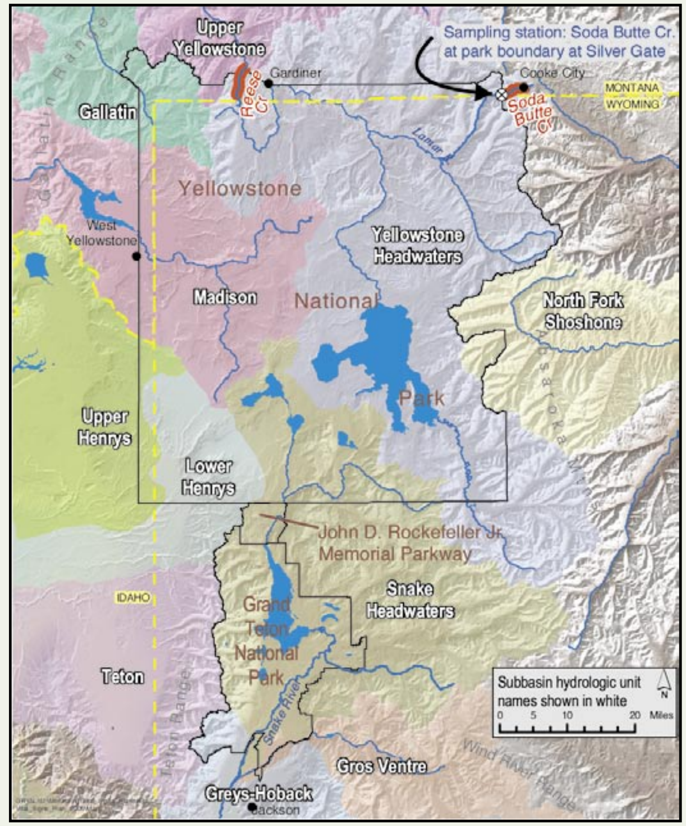
Sub-basin[1]	Documented water quality exceedances (# exceedances/ # records)	Potential causes for exceedances
Bighorn Lake: Trend = 1	Bacteriological (128/1181)	Wastewater discharge from campsites, watercraft and from the presence of cattle in and near streams flowing into the lake
	Turbidity (108/1304)	Sediment accumulation due to high sediment loads from the Shoshone and Bighorn Rivers
	Dissolved oxygen (40/1650)	*
	Nitrate-nitrogen (22/5477)	Runoff from range and cropland and wastewater treatment plants; wastewater discharges from campsites and other recreational areas
	Sulfates (546/3294)	*
	Toxic elements (298/16132)	Runoff and erosion from upstream watersheds, along with discharges from municipal areas and from industry
Shoshone: Trend =1, 2	Bacteriological (57/224)	Wastewater treatment plants upstream from BICA
	Turbidity (69/238)	Suspended sediment from the erosion of irrigated croplands, rangelands and stream banks
	Nitrate-nitrogen (17/2155)	Non-point and point sources as described for Bighorn Lake
	Sulfates (272/2510)	*
	Toxic elements (45/8951)	Runoff and erosion as described for Bighorn Lake
Lower Bighorn: Trend = 1	Sulfates (169/1154)	*
	Toxic elements (130/6061)	Runoff and erosion as described for Bighorn Lake
	Sulfates (1/73)	Geology
	Toxic elements (9/1207)	Geology; geothermal



[1] The Federal Geographic Data Committee's Subcommittee on Spatial Water Data has developed a hierarchical six level system for classifying the United States into discrete hydrologic units. The fourth level of classification is the sub-basin. Sub-basins are identified with an eight-digit Hydrologic Unit Code (HUC).

Potential causes for exceedances
*no cause suggested

Sub-basin[1]	Documented water quality exceedances (# exceedances/ # records)	Potential causes for exceedances
Yellowstone Headwaters: Trend = 5	Dissolved oxygen (18/430)	Natural characteristic of wetland areas
	pH (306/1369)	A natural characteristic of the waters of YELL
	Sulfate (97/1998)	High total sulfate associated with geothermal activity.
	Toxic elements (303/6939)	Arsenic and copper high due to geothermal influences; iron and manganese in Soda Butte Creek are likely high due to the impacts of historical mining activity
Madison: Trend = 6	pH (73/564)	Natural characteristic
	Phosphorus (1/469)	Geothermal influences
	Temperature (2/1020)	Geothermal influences
	Toxic elements (158/2178)	Geothermal influences
Gallatin: Trend = 4	pH (32/83)	Natural characteristic
	Toxic elements (6/325)	*
Upper and Lower Henry's: Trend = 4	pH (38/132)	Natural characteristic
	Toxic elements (21/404)	*
N. Fork Shoshone: Trend = 4	pH (15/32)	*
Snake Headwaters (YELL): Trend = 7	Toxic elements (74/1499)	Geothermal influences on lake water chemistry
Snake Headwaters (GRTE): Trend = 3	Bacteriological (8/704)	Sewage disposal ponds
	Turbidity (11/984)	Park roads and trails, and cattle and elk grazing.
	Dissolved oxygen (30/1717)	Natural characteristic of wetland areas
	Nitrate –nitrogen (1/2036)	Wastewater effluent, grazing of native and domestic ungulates
	pH (205/2604)	A natural characteristic of the waters of GRTE
	Sulfates (3/8951)	Geology
	Toxic elements (159/9056)	Geology; geothermal
Gros Ventre: Trend = 4	pH (11/76)	A natural characteristic of the waters of GRTE
	Toxic elements (9/1207)	Geology; geothermal



Trend

1 Increase in pH; decrease in conductivity

2 Decrease in dissolved nitrate

3 Seasonal trends only

4 Data have limited value for determining trends

5 Insufficient data to determine trends in the Yellowstone and Lamar Rivers; the Gardner River and Lake Yellowstone exhibit strong geothermal influences; Soda Butte Creek has likely been impacted by historical mining

6 Temperatures at downstream sites are lower than upstream; there is a downstream decrease in the means of dissolved sulfate, dissolved calcium and dissolved sodium

7 Weak temporal trend towards increasing total Kjeldahl nitrogen in Heart and Shoshone Lakes

IDENTIFICATION AND SELECTION OF VITAL SIGNS

The GRYN used a multistep process to identify and select candidate vital signs. One essential step involved the use of conceptual ecological models. Conceptual models provide an understanding of the structure, function and interconnectedness of park ecosystems, enabling the identification of vital signs for assessing ecosystem health. Nine terrestrial models, two aquatic models, and one geothermal model were developed. The models identified the drivers, stressors, response variables, outcomes and metrics of the ecosystem modeled, and highlighted the position of the proposed candidate vital signs within the modeled systems. Please see Chapter 2 of this report for additional information on the conceptual modeling process undertaken by the GRYN.

In addition to conceptual modeling, the GRYN used the Delphi survey process and a workshop series to further identify and prioritize vital signs. The Delphi survey was an Internet-based questionnaire sent to subject-area experts and park personnel that allowed participants to nominate possible vital signs for monitoring and then rank them on a scale of importance. The GRYN also held park-specific workshops to gain insight from park managers on the value of the conceptual modeling and Delphi results, as well as the process used to rank vital signs by their relevance. This ranking process consisted of 13 yes/no questions pertaining to the ecological relevance, response variability, managerial relevance, feasibility of implementation, and interpretation and utility of the candidate vital signs. After peer review by park staff and contributing scientists, the GRYN hosted a "vital signs monitoring workshop," during which invited subject-area experts and park managers judged the candidate vital signs using the selection criteria.

The Technical Committee then held final responsibility for selecting vital signs for approval by the Board of Directors. The selection process represented a synthesis of the information collected in the previously described exercises, as well as park-specific expertise that helped to guide the selection of vital signs that would best fulfill the needs and goals of the GRYN parks. After the selection process, the Board of Directors approved the vital signs and work began to develop specific, measurable monitoring objectives for the selected subset of vital signs that the Technical Committee ranked as top priorities. A complete list of vital signs can be found in Chapter 3 of this report along with additional information related to the selection of vital signs.

GENERAL PROCESS FOR DEVELOPING MONITORING OBJECTIVES

To guide the development of specific monitoring objectives for each vital sign selected, the GRYN chose to follow and modify the process described in Caughlan and Oakley (2001), which is represented in Figure 1.8. While most changes to the process were minor, the GRYN eliminated the use of budgetary constraints in the formation of monitoring objectives. Although cost will always be a consideration in the development of a monitoring program, the GRYN chose to eliminate costs as an initial constraint and, instead, focus on the development of specific monitoring objectives and identify tradeoffs that must be made to meet budgetary limitations.

Broad Monitoring Questions

The process used to select vital signs incorporated the ability of the prospective vital signs to fulfill the five Service-wide I&M goals, stated in section I.A.4, while also satisfying local monitoring needs and questions. Using the process depicted in Figure 1.8, the GRYN adopted three broad monitoring goals to aid in selection of vital signs and in the development of specific measurable monitoring objectives. These goals, now stated as monitoring questions, are meant to be answered by synthesizing the information gained through the specific, measurable monitoring objectives described in the vital signs protocols and also in chapter 5.

- What is the status and trend of selected ecosystem drivers and stressors currently or potentially affecting park resources?
- What is the status and trend of selected species and communities (both plant and animal) and how are they changing as ecosystem stressors and drivers change?
- What knowledge of drivers, stressors and resources of concern will affect sound management decisions and help to protect key resources or provide scientific evaluation and interpretation of ecosystem change?

Answers to these broad questions, achieved through answering specific monitoring objectives, along with information from other programs monitoring natural resources within the parks of the GRYN, present an integrated examination of the state of the parks' ecosystems.

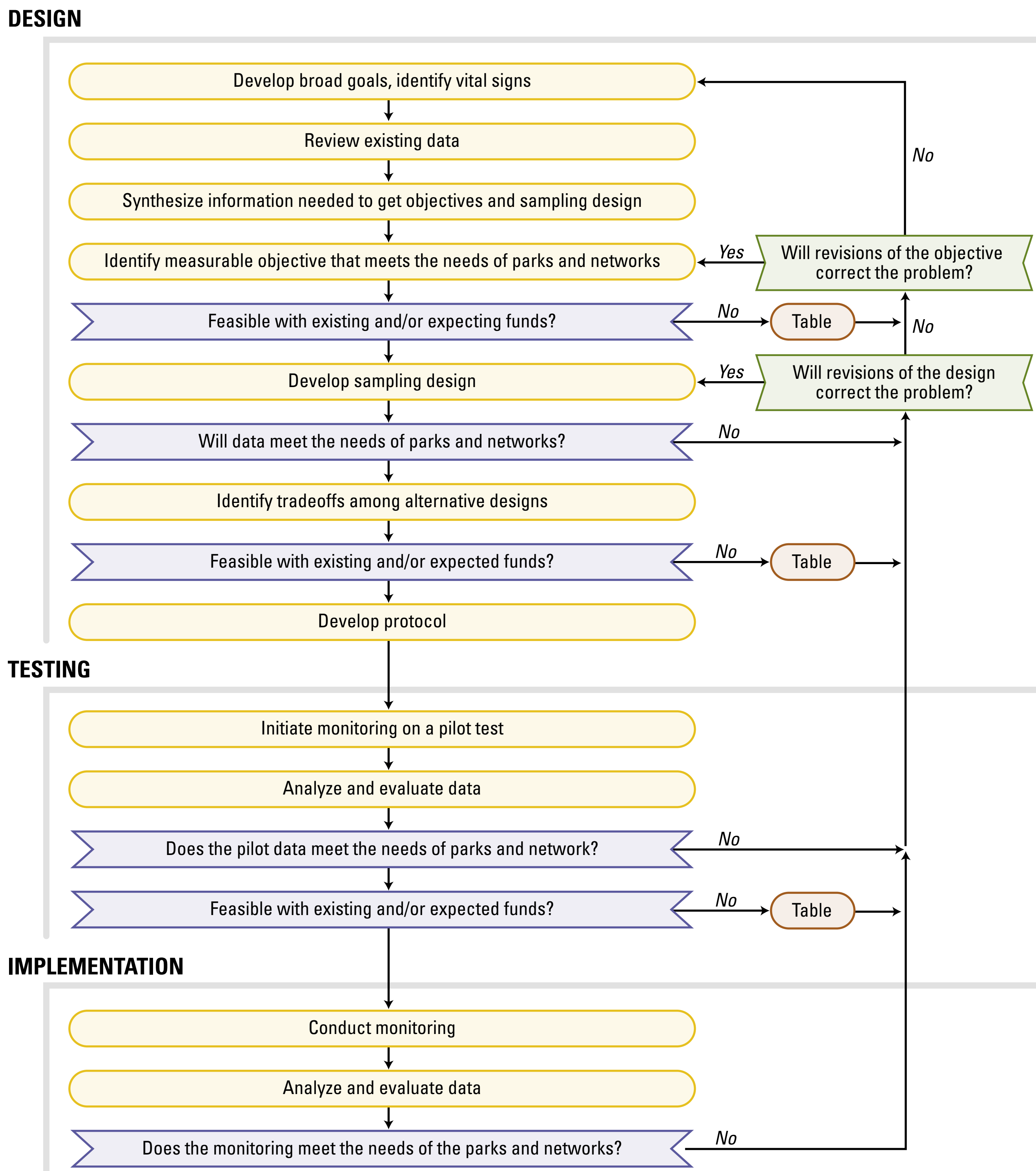


FIGURE 1.8 Diagram depicting the process used to conduct monitoring in the GRYN. This diagram is adapted from Caughlan and Oakley (2001).